An Integrated Investigation of Inner-Shelf Strata on the Eel Margin: the Coarse-Grained Portion of a Transgressive Shelf Sequence

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LONG-TERM GOALS

The ultimate goal of this research is to understand the mechanisms by which continental-margin sediment is deposited, modified and preserved, so strata recorded over various time scales (events to millennia) can be interpreted better.

OBJECTIVES

The fieldwork is undertaken on the Eel margin within the larger context of the STRATAFORM program, and has objectives that complement those of other groups. In particular, this project is designed to document event beds (i.e., flood, storm) immediately after they form, to observe their subsequent modification and preservation, and to interpret geologic history from old beds buried at various depths within the seabed (10s of centimeters to meters). These objectives were focused during the past year on the inner shelf and on Eel canyon. The work was expanded to investigate similarly a flood deposit associated with the Po River in the northern Adriatic Sea.

In addition, the overall STRATAFORM program is coordinated through efforts to: orchestrate program planning, organize field operations, and disseminate scientific results.

APPROACH

Rapid-response box coring occurred immediately after large floods of the Eel River and large ocean storms. Subsequently, the shelf and slope have been examined several times each year by box coring, piston coring, and recently by vibracoring. Investigations of sediment size and fabric are put into a chronologic context using a suite of radioisotopes (^{7}Be, ^{210}Pb, ^{137}Cs, ^{14}C), which are relevant for a variety of time scales (months to millennia). These observations were synthesized during 2001, with a focus on data from the inner shelf (<60m water depth).

Monitoring of sediment escape to the continental slope was performed at a mooring located north of the Eel River mouth in a water depth of 450 m (at site Y450). Three sediment traps (depths of 65, 200, 435 m) were maintained continuously for five years, and the temporal variability of sediment fluxes (quantity and composition) was observed on time scales of 10-16 days in sequentially rotating cups. During FY00, replicate surveys of nepheloid layers (through CTD-transmissometer profiling) were undertaken near the Y and O transects and at the head of Eel Canyon. Over a range of seasons, the

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14. ABSTRACT
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15. SUBJECT TERMS

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head of Eel Canyon was investigated by coring the seabed. An additional water-column mooring and seabed tripod were deploying at the entrance to the canyon during winter 1999-2000. These observations were synthesized during 2001.

Using rapid-response approaches developed for the Eel River, the deposit associated with a large flood (>100-y recurrence interval) of the Po River was documented soon after its formation (December 2000), and was investigated subsequently for evidence of modification (January and June 2001).

WORK COMPLETED

During 2001, laboratory analyses were completed and data was synthesized for publication of research papers, with an emphasis on the inner shelf and Eel canyon – in the STRATAFORM study area off northern California. In addition, three cruises were completed near the mouth of the Po River, in preparation for EuroSTRATAFORM. These cruises included coring and water-column observations, which provided samples for analyses of radiochemistry, sediment texture, and sedimentary structure.

RESULTS

a) Characterization of inner-shelf sand deposit – Fifty vibracores were collected, along with chirp seismic and swath bathymetry data, and can be combined with early insights from observations of sediment dynamics. From these, it becomes clear that the inner shelf (<60 m water depth) near the mouth of the Eel River is a dynamic sedimentary environment that interacts through many processes to impact the stratigraphy formed on the margin.

Sedimentary processes are evident from the seabed variability both along and across the inner shelf. A southern region has a depositional regime that is predominantly influenced by proximity to the sediment source (i.e., Eel mouth). Riverine sand is advected by the river plume ~5-10 km toward the north. Approximately 13 km away from the river mouth, inner-shelf sediment coarsens significantly. This indicates the influence of one or more alternate sediment sources, such as erosion of coastal bluffs or supply from the Mad River. The location of coarsening corresponds to the southern flank of an anticline that rises. The feature may have an indirect influence on sedimentation during modern time, but the structure more likely influenced sedimentation on the inner shelf only when it had a surface expression. Across-shelf variability in grain size is due to dynamical interactions between the sand and mud discharged by the river, and subsequent wave events that can resuspend fine sediment and winnow it from the coarser sand. In some cases, large discharge events (i.e., floods) can deposit so much fine sediment on the inner shelf that it is incompletely winnowed prior to burial by accumulating sand. Under these conditions, a distinct sedimentary record of the extreme flood is created. Some of the fine sediment may quickly settle on the subaqueous delta, and subsequently be transported by sediment-gravity flows. These removal processes leave little evidence of flood deposits, because the sediments are completely dissociated from the remainder of the flood deposit (this appears to be the situation south of the river mouth).

By identifying distinct flood events, it can be calculated that the inner shelf has been accumulating sand at a rate of 1.3-3.3 cm/y since 1964. Using the suite of data collected on the inner shelf, a sediment budget indicates that ~6-13% of the mud discharged by the Eel River accumulates on the inner shelf as a disperse deposit associated with the sand. Approximately 85-105% of the sand discharged in the river can be accounted for on the inner shelf.

b) Evaluation of sediment transport seaward from shelf to slope – Recent studies have shown that submarine canyons near large fluvial sediment sources and/or adjacent to a narrow shelf may be actively transferring terrigenous sediment offshelf during modern highstands of sea level. This study addressed the importance of the upper Eel Canyon (<1000m water depth) as a terrigenous sediment sink and conduit to the deep sea over seasonal and decadal time scales.

Radioisotopic and textural data indicate that the Eel Canyon consistently receives fluvial sediment from the Eel River during winter storm/flood seasons. ^{7}Be and x-radiographic data from box cores show that sediment is preferentially deposited in the upper canyon thalwegs (<400 m water depth) relative to canyon walls and deeper portions of the canyon (400-1000 m water depth). These data are supported by *in situ* ROV sampling, where recent sediment layers were thin on steep canyon walls and thick in channels. Near-bottom tripod data have shown that frequent down-canyon gravity-driven transport events occur in thalwegs, which may account for the observed depositional pattern. In addition, high concentration (up to 20 mg/l) intermediate nepheloid layers (INLs) have been observed at shelf break depths over the entire upper canyon, contributing to the total mass of terrigenous sediment deposited. Results show that >12% of the Eel River sediment discharge is sequestered in Eel Canyon over seasonal time scales.

^{210}Pb accumulation rates also indicate that sediment is preferentially accumulating (1.5-4.0 cm/y) in the upper thalwegs over decadal time scales. However, the spatial sedimentation pattern is not as distinct, suggesting a more complicated sedimentation history over longer time scales. Sub-bottom chirp data show that some feeder gullies may be filling with modern sediment, as indicated by thicker sediment packages within the gullies compared to steep side walls. Core data indicate that large down-canyon transport events have occurred within the main thalwegs over decadal time scales, redistributing terrigenous sediment to deeper water. A sediment budget over decadal time scales indicates that a few percent of the Eel discharge accumulates in the upper canyon. Therefore, the Eel Canyon head appears also to be an important conduit of modern terrigenous sediment.

c) *Po flood deposit* – Three cruises were undertaken (December 2000, January 2001, June 2001) in response to a major flood event (>100-y recurrence interval) that occurred on the Po River in late October. Together with Italian scientists, we participated in a cruise at the beginning of December. Similar to the 1995 and 1997 floods of the Eel River, we examined water-column turbidity and seabed characteristics. The objective was to document the flood deposit soon after its formation, so we could monitor its fate. X-radiographs of box cores demonstrate a flood deposit exceeding 20 cm in thickness near distributaries of the Po delta, with thicknesses abruptly decreasing away from the distributaries. This is in distinct contrast to the Eel flood deposit, and results from differences in terrestrial and oceanographic settings. The changes to the seabed are being monitored directly from a time series of cores at reoccupied stations.

d) *STRATAFORM coordination* – An AGU Chapman conference was planned and completed in Ponce, Puerto Rico, where the results of the program were presented. Planning for the STRATAFORM final volume continued, and chapters are presently being prepared. Continued interactions with French scientists have brought us closer to use of the Marion Dufresne for long coring on the Eel margin. Four planning workshops were held for EuroSTRATAFORM in November (Bologna), December (San Francisco), May (Arlington), and June (Ponce).

IMPACT/APPLICATIONS

For a mountainous collision margin (typical of the Pacific Ocean), this research provides data needed to understand strata formation and allows specifically for better interpretation of long cores recording the environmental history of the Eel margin. Because much of the insight gained about strata formation is generic in nature, this work interfaces with the intermediate and long time scales of the nested spectrum studied by STRATAFORM.

TRANSITIONS

The research results are being utilized by numerous other STRATAFORM groups; for example: by shelf seabed group, because radioisotopic and sedimentologic profiles are part of the integrated effort to document seabed characteristics; by boundary-layer hydrodynamics group, because observations document the seabed at instrument sites; by plume-dynamics group, because flood deposits demonstrate the fate of plume sediment; by slope sedimentation group, fluxes beyond the shelf break document sediment escape to the deep sea; by seismic stratigraphers, because core logs provide impedance profiles; by stratigraphic modeling group, because sediment accumulation rates and biological mixing rates are important parameters.

RELATED PROJECTS

As described above, examples of the related projects are: R. Wheatcroft, shelf seabed; A. Ogston, boundary-layer hydrodynamics; R. Geyer, plume dynamics; C. Alexander, slope sedimentation; N. Driscoll, seismic stratigraphy; D. Swift, stratigraphic modeling. The entire STRATAFORM program is related to the efforts for program coordination.

PUBLICATIONS (refereed publications during FY01)

Bentley, S.J. and C.A. Nittrouer, submitted. Emplacement, modification and preservation of event stratigraphy on a flood-dominated continental shelf, Eel shelf, northern California. *Jour. Sed. Res.*

Crockett, J.S. and C.A. Nittrouer, submitted. Anatomy of a sandy inner-shelf deposit. *Cont. Shelf Res.*

Mullenbach, B.L. and C.A. Nittrouer, 2000. Rapid deposition of fluvial sediment in the Eel Canyon, northern California. *Cont. Shelf Res.,* 20, 2191-2212.

Puig P., A.S. Ogston, B.L. Mullenbach, C.A. Nittrouer, R.W. Sternberg, submitted. Shelf-to-canyon sediment-transport processes on the Eel continental margin (northern California). *Mar. Geol.*

Sommerfield, C.K., R.C. Aller and C.A. Nittrouer, 2001. Sedimentary carbon, sulfur, and iron relationships in modern and ancient diagenetic environments of the Eel River Basin (USA). *Jour. Sed. Res.,* 71, 335-345.